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Original Research

The comparison of radiologic measurements of the hip parameters between girls and boys

Elisa Calısgan[1], Betül Akyol[2], Resit Sevımlı[3], Caner Cengiz Turan[4]
[1] Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Kahramanmaras Sutcu Imam University, Kahramanmaras
[2] Department of Physical Education and Sport, Faculty of Sport Sciences, Inonu University, Malatya
[3] Department of Orthopedics and Traumatology, Faculty of Medicine, Inonu University, Malatya
[4] Department of Orthopedics and Traumatology, Gözde Akademi Hospital, Malatya, Turkey

Abstract
Aim: This study aimed to compare the radiologic measurement of hip parameters between girls and boys aged 3,5 to 4 years.
Material and Methods: This retrospective study included 112 healthy children (n:57 girls, n: 55 boys) aged 3,5 to 4 years who required radiological images due to examination. Radiological images from Inonu University, Faculty of Medicine, Department of Orthopedia were used in the study. The measurements taken from the children were right and left femur head ossification, acetabular index and femur inclination angle.
Results: In girls, median right femur head ossification was 16.80 mm, median left femur head ossification was 15.30 mm, median right acetabular index was 24.10^0, median left acetabular index was 23.80^0, median right femur inclination angle was 147.40^0, median left femur inclination angle was 147.50°. In boys, median right femur head ossification was 18.40 mm, median left femur head ossification was 19.50 mm, the median right acetabular index was 17.40°, the median left acetabular index was 17.50°, median right femur inclination angle was 147.50°, and median left femur inclination angle was 148.70°.
Discussion: A statistically significant difference was found between girls and boys regarding right and left femur head ossification and acetabular index. This contributes to the determination of gender differentiation, gold standard values of hip parameters for diagnosis, evaluation and prognosis of hip diseases in children aged 3,5 to 4 years.

Keywords
Femur, Radiological, Hip, Parameters

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Corresponding Author: Elisa Calisgan, Physiotherapy and Rehabilitation Department, Faculty of Health Sciences, Kahramanmaras Sutcu Imam University, Kahramanmaras, Turkey.
E-mail: elisa.calisgan@inonu.edu.tr P: +90 534 246 24 71
Corresponding Author ORCID ID: https://orcid.org/0000 0003 4710 9540

Introduction

The largest bone in the human body is the femur, which has been researched in physical therapy, orthopedics and forensic anthropology for sex determination, diagnosis and prognosis of diseases [1-3]. A few anthropometric studies evaluated border parameters of the hip, which include distance between pubic tubercle, vertical and transverse acetabular diameter, anterior rim of acetabulum on dry hip bone using Vernier caliper [2]. Regarding age and gender, physical and forensic anthropology investigate using metric methods to determine the maxilla's difference size, meatus aquatics externus, cervical bones, femur size, tibia and fibula size, and the width of the pelvis, fetal skeletal size [4]. Although femur bone and hip parameters are used to determine age and sex, and scientists research the stage of femur ossification, there is very little knowledge available about differences in hip parameters between girls and boys. Experts still do not know the differences between sexes and how to evaluate physically and virtually [5, 6]. Hip parameters, which are acetabular diameters, femur inclination angle, the ossification of femur head, acetabular index, are suitable for evaluating sexual dimorphizms, resulting from locomotion, differentiate width of pelvis between girls and boys. Femur inclination angle is evaluated with the meeting of the axis of the femur' shaft and the femur neck axis and head [7, 8]. The femur head ossification was evaluated using the most superior, inferior, anterior and posterior points, and the distances between these points were calculated [9]. The acetabular angle is a radiological measurement used when evaluating the ossification of the epiphysis. Acetabular index, evaluation of acetabulum roof, is the standard method. In this measure, the lowest point of the cartilage Y is decided. Then the sclerotic part of the acetabulum point is determined. If the pelvic and the rear edge appear separately, both lines point where the acetabulum intersects. It should be taken with the line joining these two points, each line joining two ilium points (Hilgenreiner) is defined as the acetabular index. Average acetabular angle values should be less than 28° at birth. The angle becomes shallower progressively with age and should be less than 26^0 [10, 11].

Since, with the help of measurements taken from various anthropometric points on the femur and indices calculated from hip parameters, which have started to be used frequently in identification studies, the identification and determination of sexual differentiation in humans are commonly conducted from individuals and their radiographs, femur parameters are important to determine age and sex. Most of the studies used a device to measure portions of the femur, such as 3D models and radiography. Therefore, this study morphometrically evaluated hip parameters on radiographs [11]. There is, however, only a limited amount of data related to the parameters of the hip. To the best of our knowledge, there is no radiography study assessing the determination of sexual differentiation, the gold standard values for diagnosis and prognosis of hip diseases in children by using parameters of the hip. This study aimed to compare radiological measurements of the femur head ossification, acetabular index, and femur inclination angle (femur head/neck angle) between girls and boys aged 3,5 to 4 years.

Besides, this study's purpose is the diseases such as DDH (Developmental Dysplasia of the Hip) diagnosed in boys and girls in the 3.5-4 age group, to evaluate objectively their symptoms, their effects on walking patterns, and observe their prognosis. For this purpose, the gold standard for femoral head ossification, femur inclination angle and acetabular index values were tried to be established. It was also aimed to contribute to the literature on age and gender determination in the field of anthropology, ethnology and determine the gold standard values for the diagnosis and prognosis of hip diseases.

Material and Methods

Study design

This retrospective study was performed in compliance with the principles of the Declaration of Helsinki. The study's target population consisted of healthy children in June 2020 and July 2021 at the Department of Ortopedia, Faculty of Medicine, Inonu University. Individuals that met the inclusion criteria were selected from the target population using probable simple random sampling.

The required permission and consent were obtained from the Malatya Clinical Research Ethics Committee (approval number=2021/2324, approval date= 27/07/2021) for this study. As part of the simple random sampling method, individuals were listed by number and those to be sampled were selected using a random number table.

The study included 112 healthy children aged 3.63 ± 1.07 years. Voluntary consent form was obtained from the participants' families before the survey. Children who agreed to participate in the study and met the inclusion criteria were selected by a randomized sampling method in the relevant phase. Hip parameters of children aged 3,5 to 4 years are suitable for evaluating sexual dimorphizim. Age and locomotion have an effect on hip parameters; therefore, this study included paticipants who have the ability of locomotion. Also, femur head ossification was better observed in children with aged 3,5-4 years. The inclusion criteria were healthy Turkish children aged 3,5-4 years, adapting to the study.

Children were excluded from the study if they were outside the age range of 3,5-4 years, had an existing health problem such as developmental hip dysplasia, obesity, did not adapt to this study, or did not are approved by families.After applying these criteria, 20 children were excluded (four girls with hip subluxation, six boys with hydrocephalus, ten children's families not willing to participate in the study).

Data collection

The demographic information and clinical characteristics of the children were recorded, including age and gender.

The femur head ossification size was evaluated using radiographs of both girls and boys aged 3,5-4 years (Figure 1). The most superior, inferior points and distances between these points were calculated. The radiographs are essential and recommended for evaluation because of high reliability [9, 11].

The acetabular index angle was evaluated in both girls and boys aged 3,5-4 years (Figure 2). Acetabular index was measured as the angle, which is a line connecting the lowest and lateral points of the iliac bone in the triradiate cartilage, the most supero-lateral point of the acetabulum and the Hilgenreiner line

connecting the lowest end of iliac bones in both hips. Average values of the acetabular index angle should be less than 28^0 at birth. The grade becomes shallower progressively with age and should be less than 26^0 [12, 17].

Femur inclination angle was evaluated with the meeting of the axis of the femur' shaft and the femur neck and head (Figure 3). There is an angle of 125-130^0 between head and neck and femur body [13, 14].

Evaluation of femur head ossification, acetabular index angle and femur inclination was made using radiography.

Statistical analysis

Data obtained in the study were analyzed using IBM-SPSS Statistics 22.0 software. The Shapiro-Wilk test was used for evaluating normality. The Mann-Whitney U test was used to compare the significance of data that did not meet normality conditions. Results of the measured values were stated as median (min, max). In the power analysis performed, assuming that the difference between the acetabular index [14] (1 unit with α = 0.05 and 1-β (power) = 0.80, at least 25 patients (50 hips) were required for the sample. P<0.05 was accepted statistically significant [15].

Results

The evaluation of 112 healthy children (224 hips) was done, including 57 girls (114 hips; right: 57 hips, left: 57 hips) and 55 boys (110 hips; right: 55 hips, left: 55 hips) with a mean age of

Table 1. Comparison of Femur Head Ossification and Acetabular Index Between Girls and Boys

Parameter	Boys (n:55)	Girls (n:57)	p
Femur Head Ossification (mm) (Right)	18.40 (12.90-26.20)	16.80 (6.50-22.30)	0.05[a]
Femur Head Ossification (mm) (Left)	19.50 (10.90-24.90)	15.30 (5.30-23.90)	0.003[a]
Acetabular Index (degree) (Right)	17.40 (9.80-26.50)	24.10 (17.00-30.30)	<0.001[a]
Acetabular Index (degree) (Left)	17.50 (10.00-23.30)	23.80 (17.40-32.90)	<0.001[a]

p<0.05, Min: Minimum, Max: Maximum, a:Mann-Whitney U Test; the data are presented as medians (min, max)

Table 2. Comparison of Femur Inclination Angle Between Girls and Boys

Parameter	Boys (n:55)	Girls (n:57)	p
Femur Inclination Angle (degree) (Right)	147.50 (135.40-164.90)	147.40 (124.70-157.20)	0.116[a]
Femur Inclination Angle (degree) (Left)	148.70 (137.80-155.90)	147.50 (124.40-159.70)	0.686[a]

p<0.05, Min: Minimum, Max: Maximum, a:Mann-Whitney U Test; the data are presented medians (min, max)

Table 3. ROC Analysis of Femur and Acetabular Parameters

	AUC	Sensitivity	Specificity	p
Femur Head Ossification (Right)	0.313	42.10	52.60	0.049
Femur Head Ossification (Left)	0.226	42.10	73.70	0.004
Acetabular Index (Right)	0.891	89.50	36.80	<0.001
Acetabular Index (Left)	0.884	89.50	31.60	<0.001
Femur Inclination Angle (Right)	0.349	52.60	63.20	0.112
Femur Inclination Angle (Left)	0.460	52.60	57.90	0.672

Figure 1. Measurement of Femur Head Ossification

Figure 2. Measurement of Acetabular Index

Figure 3. Measurement of Femur Inclination Angle

3.63 ± 1.07. years (range: 3,5-4 years). It has been determined that the age variable does not affect the right and left femur head ossification, right and left acetabular index, right and femur inflation angle (p:0.397, p:0.237, p:0.521, p:0.659; p:0.675, p:0.857, respectively). No statistical differences were determined in respect of age between girls and boys (p:0.751).

In the intra-group analysis, statistically significant results were observed at all time intervals regarding right and left femur head ossification of girls and boys (p:0.05, p:0.003, respectively) (Table 1). Statistically significant differences were determined in respect of right and left acetabular indexes between girls and boys (p<0.001) (Table 1). There was no statistically significant difference in terms of right and left femur inclination angles between girls and boys (p>0.05) (Table 2).

Boys had higher points than girls with the significance of right and left femur ossification and lower points acetabular index than girls (Table 1).

Femur head ossification (right and left) is significant for determining the cut-off value of the difference between girls and boys (respectively; p:0.049, p:0.004) (Table 3).

The acetabular Index (right and left) is significantly essential to determine the cut-off value of the difference between girls and boys (p<0.001) (Table 3).

Femur Inclination Angle (right and left) is not significant for determining the cut-off value of the difference between girls and boys (respectively; p:0.112, p:0.672) (Table 3).

Discussion

This study investigated comparing radiological measurements of the femur head ossification, acetabular index and femur inclination angle between girls and boys aged 3,5 to 4 years. The results demonstrated that the right and left femur head ossification points, acetabular index in boys were higher than in girls. To the best of our knowledge, this is the first study to compare right and left femur head ossification, acetabular index and femur inclination angle between girls and boys aged 3,5-4 years.

According to previous studies, the size of femur head ossification was seen more prominent in boys aged 3,5-4 years because of a higher acetabulum score [15, 16]. In the current study, right and left femur head ossification and the acetabular index showed high score in boys aged 3,5-4 years. The conclusion of this study was similar to those of previous studies regarding the determination of gender differentiation from femur head ossification in children.

Previous studies have shown that there are differences between the genders in terms of the femur's proximal and distal parts, according to studies of the proximal end of the femur used to determine sexual differentiation in humans. However, the distal femur part is not used to determine sexual differentiation [17, 18]. This conclusion was similar to the conclusion of the current study. This study also compared sex differentiation in children in terms of femur head ossification (distal femur part).

Kim et al. [19] compared the femur's width and lateral condyles between girls and boys. They studied sex determination in 202 Koreans femur using the width of the lateral and medial femoral condyles. They found that the width of the medial and lateral condyles of the femur should help determine sex differentiation. This conclusion was similar to the conclusion of the current study regarding the determination of sex differentiation from femur head ossification in children.

Incesu et al. observed that acetabular index is measured higher in the left hip due to intrauterine positioning. It was suggested that the acetabular index should not used over eight years because of inconsistency in determining measurement points. In the case of radiographs, which were not evident in children, the risk of measurement differences was higher [20].

Nieves et al. investigated the differentiation of the femur neck size and total femur bone between girls (n:36) and boys (n:36). They found that boys have larger femur bone area, bone mineral density, and femur neck than girls. They concluded that femur bone parameters in males are higher than in females [21]. This conclusion was similar to the conclusion of the current in terms of femur bone parameters. Boys have larger femur head ossification than girls. However, this study did not evaluate the comparison of bone mineral density between girls and boys.

This study evaluated ossification of the femur head, acetabular index and femur inclination angle in children aged 3,5-4 years. Femur head ossification and acetabular index should be helpful for the determination of sexual differentiation. However, there was no statistically significant difference in terms of right and left femur inclination angles between girls and boys. In other words, right and left femur inclination angles should not help determine sex differentiation.

A limitation of the current study was that the width of acetabulum and femur density were not evaluated. Since radiographic imaging is harmful in healthy children due to radiation exposure, our study's number is low. Therefore, the number of patients in the study may be higher. Also, the age group can be established in girls and boys.

Conclusion

In conclusion, this study demonstrated that femur head ossification and acetabular index should help determine sexual differentiation in children. This study provides further evidence on how radiological measurements taken from girls and boys aged 3,5 to 4 years differ in terms of femur head ossification, acetabular index, and femur inclination angle (femur head/neck angle). Also, it contributes to diseases such as DDH (Developmental Dysplasia of the Hip) diagnosed in boys and girls in the 3.5-4 age group to evaluate their symptoms, their effects on walking patterns objectively, and observe their prognosis. For this purpose, the gold standard of femoral head ossification, femur inclination angle and acetabular index values were established.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest
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